

## §9. Identification of Effective Plasma Boundary in High-beta Plasmas

Suzuki, Y., Ida, K., Yoshinuma, M., Sakakibara, S., Watanabe, K.Y., Ohdachi, S., Kamiya, K. (JAEA)

For general three-dimensional (3D) systems, the magnetic field structure becomes easily stochastic because it is no symmetry. In such a case, the definition of the plasma boundary is a big problem where is the plasma boundary.

Usually, the Last Closed Flux Surface (LCFS) can be used as a plasma boundary. However, for high- $\beta$  plasmas, the magnetic field structure is changed by the “3D plasma response”<sup>1)</sup> and a significant pressure gradient is observed in the edge region where the three-dimensional magnetohydrodynamics equilibrium analysis predicts the stochasticization of magnetic field lines<sup>2)</sup>. This suggests the LCFS is not an “effective plasma boundary” of the plasma because there is a possibility the stochastic region is still the plasma confined region.

Recently, in LHD experiments, the radial electric field is studied in the peripheral region<sup>1, 3)</sup>. If electrons are lost along the open field lines of the stochastic field, a positive  $E_r$  might appear. This means that the positive  $E_r$  or strong  $E_r$  shear suggests the appearance of the effective plasma boundary between open and closed field lines.  $E_r$  shear profiles are compared with 3D MHD equilibrium calculations. Positions of maximum  $E_r$  shear correspond the edge of the stochastic layer. However, those studied very collisional plasma of low- $T_e$  and high- $n_e$ . The extensive study in the collisionless plasma is necessary with the sensitivity of the electron transport along stochastic field lines.

An advantage of the LHD device is the flexibility of the width of the stochastic layer in the vacuum magnetic field. In the LHD device, the vacuum magnetic configuration can be controlled by the preset vacuum axis position,  $R_{ax}$ . The preset vacuum magnetic axis position of the inward shifted configuration is 3.6m and that of the outward shifted configuration is 3.9m. In both configurations, clear flux surfaces are seen inside the vacuum LCFS. The outer position of the LCFS for the inward shifted configuration is  $R=4.55$ m on the  $Z=0$  line. For the outward shifted configuration, the position of the LCFS is  $R=4.56$ m on the  $Z=0$  line. This means the position of the vacuum LCFS is almost the same in both configurations. Outside of the LCFS, open field lines appear and the magnetic field lines become stochastic. Especially, for the outward shifted configuration, the width of the stochastic layer is wider than that of the inward shifted configuration. At the region for  $R > 4.65$ m, opened and closed field lines overlap in the stochastic layer. Since the stochasticity of the magnetic field in the peripheral region can be controlled for the

vacuum field, LHD is a good platform to study MHD and transport in a stochastic field. Thus, two magnetic configurations with thin stochastic layer ( $R_{ax}=3.6$ m) and wider stochastic layer ( $R_{ax}=3.9$ m) are studied with collisionless plasmas of high- $T_e$  and low- $n_e$ .  $E_r$  profiles are measured for  $R_{ax}=3.6$  and 3.9m configurations and  $E_r$  shear are calculated. Purple arrows indicate the position of vacuum LCFS. For  $R_{ax}=3.6$ m configuration, the  $E_r$  increases at  $R > 4.5$ m then  $E_r$  is zero at  $R \sim 4.57$ m. A strong  $E_r$  shear appears in that region. In that region, finite  $T_e$  exists but  $\nabla T_e$  is sufficiently small at  $R > 4.57$ m. This point is almost the edge of the vacuum stochastic layer. On the other hand, for  $R_{ax}=3.9$ m configuration, the  $E_r$  is increased at  $R > 4.65$ m then  $E_r$  is zero at  $R \sim 4.68$ m. This point is also the edge of the vacuum stochastic layer. In this shot, the finite  $T_e$  exists similar to the inward shifted configuration and  $\nabla T_e$  is small outside of the strong  $E_r$  shear region. These results reflect differences of the width of the stochastic layer in the vacuum magnetic field.

- 1) Suzuki Y. *et al.* 2013 *Nucl. Fusion* **53** 073045.
- 2) Suzuki Y. *et al.* 2009 *Plasma Fusion Res.* **4** 036.
- 3) Kamiya K. *et al.* 2013 *Nucl. Fusion* **53** 013003.

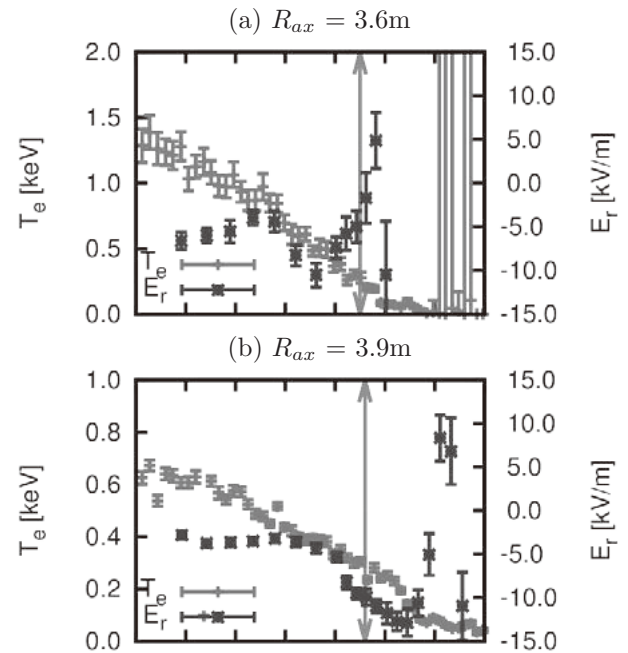


Fig. 1: Profiles of the radial electric field for (a) inward and (b) outward shifted configurations are shown as a function of  $R$ , respectively. For reference, electron temperature profiles for both configurations are also plotted. The purple arrow indicates the position of the vacuum LCFS.